

# 11 Engineering Surveys

Engineering surveys gather data for use by planners and engineers. The products resulting from engineering surveys are generally topographic maps and/or a digital terrain model (DTM). Both conventional (on the ground) and photogrammetric methods are used to gather data for engineering surveys. This section provides standards, procedures, and general information for performing conventional engineering surveys using the Caltrans Total Station Survey System (TSSS), GPS, and differential leveling. For a discussion of photogrammetric surveys, see Section 15, “Photogrammetric Surveys.”

## **11.1 Responsibilities**

Successful engineering surveys require close cooperation between Planning/Design and Surveys.

### **Project Manager**

The Project Manager is an engineer who leads the Project Development Team and is responsible for overall project planning and completion.

It is the responsibility of the Project Manager to:

- Ensure that all survey requests are accurate and specific.
- Obtain right of entry, as needed, for surveys outside existing Caltrans right of way.

### **Project Surveyor**

The Project Surveyor is appointed by the District Surveys Engineer to:

- Participate as a member of the Project Development Team.
- Coordinate with other functional areas.
- Review and schedule each engineering survey request.
- Determine the appropriate method to accomplish the requested surveys in cooperation with the project manager.
- Create and maintain a survey project file.

## 11.2      **Prejob Meeting**

As soon as a project is known, e.g., appears on the Status of Projects Report or an initial survey request is received, the Project Surveyor should schedule a meeting with the Project Manager to discuss anticipated survey requests. The meeting with the Project Manager should cover:

- Project Schedule
- Acquisition of any critical information not included in the initial survey request such as as-builts, alignments, etc.
- Overall project survey needs
- Alternative survey methods
- Safety considerations
- Recommendations for survey methods
- Appointment of Project Surveyor to the Project Development Team
- Surveys that might be eliminated because of existing data
- Accuracy requirements for the survey
- Additional survey needs (right of way, construction, etc.)

## 11.3 Engineering Survey Request

All engineering surveys are initiated by a written request from the Project Manager or designee. Requests should be directed to the District Surveys Engineer or the Project Surveyor if one has been appointed.

Survey requests should contain the following information:

- Requestor's name, phone number, and functional area
- Date of request
- County, Route, and kilometer post (post mile) of beginning and end of project
- Expenditure authorization and special designation
- Applicable work breakdown (WBS) codes
- Specific date needed (ASAP is not acceptable)
- Description of work requested
- Expected work product
- Sketch of the area to be surveyed showing lateral limits for the survey and beginning and end of work area
- Signature of the Project Engineer or Project Manager (senior level or above)

See Figure 11-1, for sample survey request form.

Survey requests should be date stamped and then reviewed by the District Surveys Engineer or the Surveys Project Management Coordinator.

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION <b>REQUEST FOR SURVEY</b> RW-0605 (Rev. 12/96)					REQUEST DATE													
TO: DISTRICT SURVEY OFFICE  Senior Land Surveyor					PROJECT NAME													
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SURVEY REQUEST PURPOSE																		
WORK LIMITS																		
SURVEY PRODUCTS																		
DESIGNER EWS PATHNAME (if applicable)				ALIGNMENT BASEMAP FILENAMES (if applicable)														
<b>NOTE:</b> All electronic files provided by SURVEYS can be found on the engineering workstation at:																		
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BY:																		
PROJECT MANAGER (PLEASE PRINT)																		
PHONE		BRANCH																
SIGNATURE—SENIOR ENGINEER				SIGNATURE—SURVEY AREA SUPERVISOR		DATE												
FM3064 M96																		

**Figure 11-1. Request for Survey Form**

## 11.4 Planning

Planning begins with the meeting between the Project Surveyor and the Project Manager to discuss the proposed survey request. See Section 11.2, “Prejob Meeting.” From a planning perspective, an important part of this meeting is obtaining information about anticipated future related survey requests for the project. Consideration of future right of way surveys and construction surveys should be part of the planning process so that the most efficient survey work plan for the overall project can be formulated.

A work plan for engineering surveys is prepared by the Project Surveyor. This work plan should contain:

- A list of the required engineering survey products
- A schedule for the requested project surveys, including critical milestones
- Resource needs (personnel, equipment, cash overtime, travel expense)

Planning may require contact with the following offices:

Caltrans Program	Information to Request
Permits	Will consultants, contractors, or others be working in or near the project area?
Traffic Operations	What is the average daily traffic, peak hour traffic, and feasibility of traffic controls, including lane and shoulder closures?
Maintenance ( <i>Maintenance Engineer, Area Superintendent</i> )	Are lane closures are currently planned in the area by Maintenance and, if so, can they be jointly used for the survey effort?
Safety	Advice concerning non-routine safety issues.
Environmental	Information concerning any potential environmentally sensitive aspects.
Hazardous Waste	Does the area contain hazardous waste? Is special training needed?

### **11.4-1      Safety Planning**

Safety should be a prime consideration in all survey planning and especially with engineering surveys, which often require work in and around traffic. A key planning consideration is to reduce (minimize) the overall exposure of surveyors to traffic. This can be accomplished in part, by carefully selecting the survey method, choosing the time to perform the survey, and employing special survey techniques. See Section 11.7-3, "Pavement Elevation Surveys – Safety" and Section 2, "Safety."

## 11.5 Research

Research for the engineering surveys should be part of the research for the overall project. Research for engineering surveys and control surveys should be undertaken at the same time.

Identify existing survey control in the area. When necessary, plan a control survey that will meet the requirements of the initial survey request as well as anticipated future project surveying needs. See Section 10, “Project Control Surveys.”

Research information in Caltrans files so that all existing aerial photos, topographic mapping, monumentation maps, USGS maps, and as-built plans are identified. This will ensure that work accomplished on a previous project or survey request will not be duplicated.

Search the records and files of other government agencies, utility companies, and railroads for information on facilities located in the project area. Potential agencies include:

- Federal agencies: Bureau of Land Management, Bureau of Reclamation, Army Corps of Engineers, and U.S. Forest Service.
- State agencies: Department of Parks and Recreation, Department of Water Resources, and State Lands Commission.
- Local public agencies: County and city public works departments, transit districts, reclamation districts, flood control districts, public utility districts, park districts, water districts, and community service districts.
- Private utility companies: Railroad, electrical power, telephone, cable TV, natural gas, pipeline companies, and water companies.

Obtain vesting documents for all recorded easements.

A data base of local contacts for survey research efforts should be maintained by each Surveys Branch. A simple, searchable, digital data base can be used for this purpose. Each record should contain the name of the agency or company, address, phone numbers, and the name of contacts. Special care should be taken to keep contacts friendly. Prompt payment for information that is purchased and letters thanking cooperative staff go a long way to improving research efforts.



## 11.6 Office Preparation

The Project Surveyor, in consultation with the field supervisor and party chief, is responsible for the development of the necessary instructions and information (field package) for performing the requested engineering surveys. Surveys office staff, under the direction of the Project Surveyor, generally prepare the field package using information obtained from the research, together with other compiled and computed data. The field package should contain all the necessary information and data to efficiently complete the field work required by the survey request. Typical information/data that may be included are:

- Copy of survey request (always included)
- Special instructions including safety and hazardous waste considerations (always included)
- Control diagram and station listing
- As-built plans
- Monumentation and right of way maps and monument listing
- Maps of record
- Utility maps
- Utility easement descriptions
- Data in digital format
  - Control data: descriptions, coordinates, elevations
  - Monumentation data: descriptions, coordinates
  - Topo data: descriptions, coordinates, elevations
  - Alignment data

## **11.7 Field Work**

Field work should not be initiated without a completed field package, including survey request form and written instructions designating any special survey needs.

### **11.7-1 General**

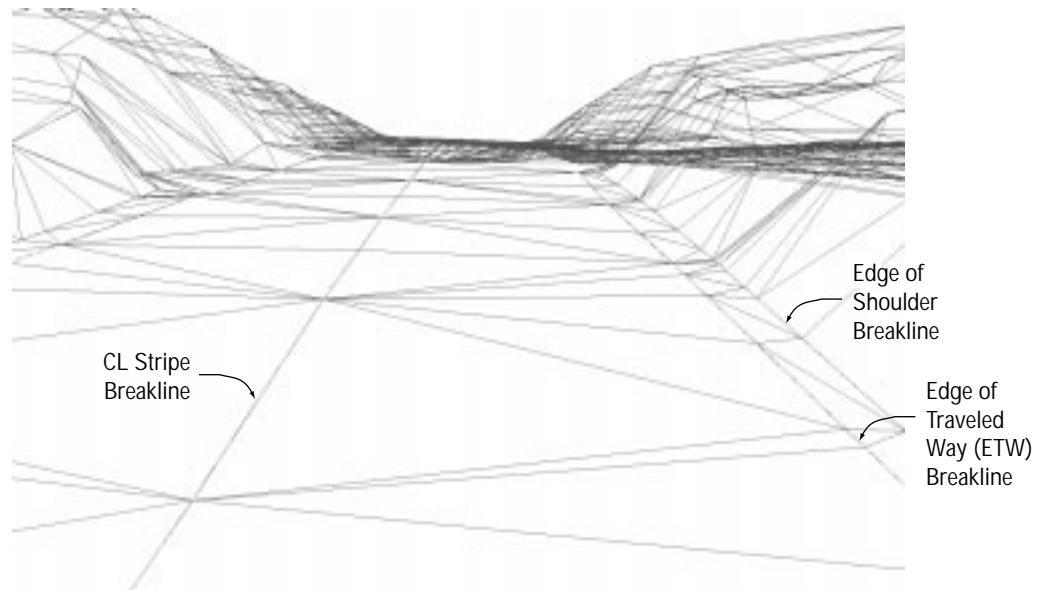
Data collectors should be downloaded daily. Files should be transferred to a laptop computer hard drive and then backed up on a floppy disk. File naming conventions can be used to keep track of raw data files for each day of work for large survey requests. Data files for each job should be located in a job directory. Any comments, descriptions of special circumstances, and narratives of the work should be stored in a read.me subdirectory of the job directory.

Field crews should check their own work before sending it to the office section. Field crews located in remote areas must check their work before returning to their headquarters office. All work by field crews must be independently checked in the district office. Responsibility for final checking of all survey products, including DTMs, rests with the district office data processing staff.

### **11.7-2 Topographic Survey**

Topographic surveys are undertaken to determine the configuration of the earth's surface and the locations of natural and manmade objects and features. The products of topographic surveys, digital terrain models (DTMs) and topographic maps are the basis for planning studies and engineering designs.

A DTM is a representation of the surface of the earth using a triangulated irregular network (TIN). The TIN models the surface with a series of triangular planes. Each of the vertices of an individual triangle is a coordinated (x,y,z) topographic data point. The triangles are formed from the data points by a computer program which creates a seamless, triangulated surface without gaps or overlaps between triangles. Triangles are created so that their sides do not cross breaklines. Triangles on either side of breaklines have common sides along the breakline. (See Figure 11-2.)



**Figure 11-2**

Breaklines define the points where slopes change in grade (the intersection of two planes). Examples of breaklines are the crown of pavement, edge of pavement, edge of shoulder, flow line, top of curb, back of sidewalk, toe of slope, top of cut, and top of bank. Breaklines within existing highway rights of way are clearly defined, while breaklines on natural ground are more difficult to determine.

DTMs are created by locating topographic data points that define breaklines and random spot elevation points. The data points are collected at random intervals along longitudinal break lines with observations spaced sufficiently close together to accurately define the profile of the breakline. Like contours, break lines do not cross themselves or other break lines.

Cross-sections can be generated from the finished DTM for any given alignments.

**Method:** When creating field-generated DTMs, data points are gathered along DTM breaklines, and randomly at spot elevation points, using the TSSS radial survey method. This method is called a DTM breakline survey. Because the photogrammetric method in most cases is more cost effective, gathering data for DTMs using field methods should be limited to small areas or to provide supplemental information for photogrammetrically determined DTMs. The ESC Photogrammetry Section routinely merges field-generated terrain data (often pavement elevations) with photogrammetric data to produce a DTM.

The number of breaklines actually surveyed can be reduced for objects of a constant shape such as curbs. To do this, a standard cross section for such objects is sketched and made part of the field notes. Field-collected breaklines are identified by line numbers and type on the sketch along with distances and changes in elevation between the breaklines. With this information in the field notes, only selected breaklines need to be located in the field, while others are generated in the office based on the standard cross section.

### **Advantages of DTM breakline surveys:**

- Safety of field crews is increased because need to continually cross traffic is eliminated.
- Observations at specific intervals (stations) are not required.
- New sets of cross sections can be easily created for each alignment change.

### **DTM survey guidelines:**

- Remember to visualize the TIN that will be created to model the ground surface and how breaklines control placement of triangles.
- Use proper topo codes, point numbering, and line numbers.
- Use terrain code 701 for critical points between breaklines, around drop inlets and culverts, and on natural ground in relatively level areas.
- Make a sketch of the area to be surveyed identifying breaklines by number.
- Do not change breakline codes without creating a new line.
- Take shots on breaklines at approximately 20 m intervals and at changes in grade.
- Locate data points at high points and low points and on a grid of approximately 20 m centers when the terrain cannot be defined by breaklines.

- If ground around trees is uniform, tree locations may be used as DTM data points by using a terrain code of 701.
- Keep site distances to a length that will ensure that data point elevations meet desired accuracies.
- Gather one extra line of terrain points 5 to 10 m outside the work limits.

**Accuracy Standard:** Data points located on paved surfaces or any engineering works should be located within  $\pm 10$  mm horizontally and  $\pm 7$  mm vertically. Data points on original ground should be located within  $\pm 30$  mm horizontally and vertically.

**Checking:** Check data points by various means including reviewing the resultant DTM, reviewing breaklines in profile, and locating some data points from more than one setup.

**Products:** The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be kept in digital form and include the following items:

- Converted and adjusted existing record alignments, as requested. (CAiCE project subdirectory)
- Surveyed digital alignments of existing roadways and similar facilities. (CAiCE project subdirectory)
- CAiCE DTM surface files. (CAiCE project subdirectory)
- 2-D CADD Microstation design files, .dgn format.
- Hard copy topographic map with border, title block, labeled contours, and planimetry.
- File of all surveyed points with coordinates and descriptions. ((CTMED, .rpt, format)

### 11.7-3 Pavement Elevation Surveys

A significant portion of today's transportation program consists of rehabilitation and other improvements of existing facilities. For these projects, elevations of existing pavements are often required to develop accurate plans, specifications, and estimates. Because of safety considerations, surveyors need to carefully select methods and procedures for conducting pavement elevation surveys.

Until recently, the only practical method to acquire pavement elevation data was through conventional leveling or TSSS methods. Both of these methods require surveys to be performed in, or adjacent to, moving vehicular traffic and can necessitate the use of temporary traffic controls including lane closures.

Alternate methods for determining pavement elevations, such as remote observations and photogrammetry, are now available and should always be considered. It is the responsibility of the Project Surveyor, in cooperation with the field supervisor and the requesting Project Manager, and with the assistance of Safety, Traffic Operations, Maintenance, and Permits functions, to determine the survey method or system that is most appropriate for a project.

When a request for a pavement elevation survey is received, the Project Surveyor should cooperate with staff from the following functional areas:

- **Requesting Project Engineer:** Determine (a) the overall objectives of the survey, (b) possible areas that can be eliminated to reduce the amount of data collection required, (c) realistic delivery times, and (d) the pavement elevation accuracy requirements. Key objective: determine, in cooperation with the Project Engineer, what is the minimal amount of data, if any, that is necessary to obtain a quality design.
- **Permit Engineer:** Determine if consultants, contractors, or others are, or will be, working near the project location.
- **Traffic Operations:** Obtain information on average daily traffic, peak hour traffic, and feasibility of traffic controls, including lane and shoulder closures.
- **Maintenance:** Coordinate survey activities with the maintenance engineer and area superintendent. Determine if maintenance activities, which will require lane closures, are planned for the survey area. Possibly, a maintenance lane closure can be jointly used for the survey effort.
- **Safety:** Solicit comments and advice from the District Safety Office whenever safety issues arise that are not routine.

**Note:** Remember, the need for a pavement elevation survey should always be questioned. The use of as-built information, existing survey data, or other record data should be considered before performing a pavement elevation survey. Request the Project Engineer to consider alternate design methods or procedures that do not require pavement elevations or require less accurate pavement elevations.

For instance, if concrete barriers will be installed for construction, discuss with the Project Engineer the feasibility of collecting accurate pavement elevations after the barriers are installed, but before establishing (staking) the final grade. With this method, the design is based on available data and then refined based on accurate pavement elevations collected during construction.

## **Safety**

Pavement elevation surveys are one of the most hazardous surveys performed by Caltrans surveyors. It is imperative that safe surveying practices be employed for such surveys.

Caltrans Director's Policy Number 03 states in part that "Caltrans conducts its business, provides services, and designs, constructs and maintains facilities in the safest possible manner consistent with applicable laws, rules, and policies."

In accordance with Caltrans "Code of Safe Surveying Practices" (see Section 2, "Safety"), safety shall be given top priority in the planning of all surveys. For pavement elevation surveys, a key planning consideration is to reduce (minimize) the overall exposure of surveyors to traffic. This can be accomplished, in part, by carefully selecting the survey method, choosing the time to perform the survey, and employing special survey techniques. In addition, when planning pavement elevation surveys, safety of the traveling public must be a priority consideration.

Prior to commencing each pavement elevation survey, a tailgate safety meeting shall be conducted. All those involved in the pavement elevation survey must participate in the meeting and discuss all safety aspects of the survey. The meeting must be documented.

Close coordination between the Surveys Office and the District Safety Office must be maintained.

**Method:** Innovative methods for pavement elevation surveys have been developed by Caltrans and others. Whenever appropriate, new surveying technologies should be employed to reduce exposure of surveyors to traffic hazards. See Section 11.7-4, “Pavement Elevation Survey Methods.”

**Accuracy Standard:** Data points should be located within  $\pm 10$  mm horizontally and  $\pm 7$  mm vertically.

**Checking:** Data points are checked by various means including reviewing breaklines in profile and locating some data points from more than one setup.

**Products:** The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- CAiCE DTM surface files. (CAiCE project subdirectory)
- Files of all surveyed points with coordinates and descriptions. (CTMED, .rpt, format)

## 11.7-4      **Pavement Elevation Survey Methods**

Various pavement survey methods are discussed in detail below to aid in the selection of the best method for a given survey.

### 1. **Conventional (TSSS) Survey:**

**Description:** Locate data points on pavement breaklines using the TSSS radial survey method. See section 11.7-2, “Topographic Survey.” Accuracy of survey data points are within 7 mm.

Several methods have been used successfully to aid the surveyor to continually monitor traffic while making observations at the edge of a roadway. Two of these methods are:

- Stand to the side of the pavement breakline and hold the prism rod inverted, at an angle, with the prism directly on the observation point. The instrument operator sights the intersection of the prism and pavement (zero height of target).
- Utilize an expendable prism (sign reflector) mounted in a small (2.5" diameter) piece of material from a cone base. The expendable prism is placed directly on the point of observation, and the instrument operator sights as noted above.



The main disadvantage to the DTM breakline method is that it normally cannot be used to obtain interior breakline elevations (e.g., crown lines) without lane closures.

**Production:** Production varies depending on traffic, road profile, and number of breaklines. A four-person survey party is recommended. In light-to-moderate traffic, 200 to 250 observations per day can be expected. This equates to 1200 to 1600 m per day of roadway, with four to five pavement breaklines. Production is reduced significantly by heavy traffic conditions and complexity of highway cross sections. Additional breaklines significantly reduce production. Survey costs increase significantly if lane closures are necessary.

## 2. Trigonometric Surveys:

**Description:** Several districts have devised trigonometric methods to determine pavement elevations using the TSSS without the use of a prism. These methods have been used successfully to supplement conventional pavement elevation surveys. Accuracy of survey data points are within 7 mm.

Following are two such methods:

- **Defined Line/TSSS:** This method, developed by District 7, requires a known roadway (as-built) alignment that is consistent with (a) existing, well-defined, as-built roadway features (e.g., edge of pavement, edge of gutter, etc.) and (b) existing project control. Station/offset coordinates are pre-calculated for each required pavement elevation location. Direction and distance are then calculated from a specific, known control point to each pavement elevation location. In the field, a TSSS is used to observe the known direction and to measure the unknown vertical angle to each pavement elevation location from a known control point. The predetermined distance, observed direction, and measured vertical angle are used to create a data file from which pavement elevations are calculated. Predetermined distances and directions can be calculated using an HP-41 calculator program developed by District 7.
- **Two TSSS/Laser Dot:** Another similar method, which employs two TSSS and a low-power laser, was devised by District 11. With this method, simultaneous horizontal and vertical TSSS measurements are made from two known control points to a random pavement point defined by directing a laser beam onto the pavement surface at the location desired. The laser beam provides a sight point for the simultaneous TSSS observations. District 11 personnel have developed a

HP-41 hand-held calculator program to assist in computing the pavement elevations. (Prior to using this method, review the latest safety regulations concerning the operation of laser devices.)

**Note:** The advantage of trigonometric methods over the conventional method is that surveyors are not required to work adjacent to traffic. Additional costs are incurred because of the need for very accurate alignment data for the Defined Line/TSSS method and the need for larger survey crews for the Two TSSS/Laser Dot method. Both methods require an expanded control network and more time for computations.

**Production:** Varies depending on number of breaklines. Generally, less production than the normal DTM breakline method.

### 3. Remote Observations

**Description:** This system allows DTM data to be collected remotely from a survey vehicle (van) located on the shoulder of a roadway using an EDM that does not require a prism. During data collection operation, the van proceeds in a “stop-and-go” process with each stop lasting five to ten minutes while observations are conducted for 30 to 100 m of roadway. Use of the system is dependent on availability of a firm or paved shoulder wide enough for the van to provide separation from traffic. Accuracy of survey data points is within 7 mm.

Surveys can be performed with this system without surveyors working in traffic and without the use of lane closures (except in the case of ramp gores and bridges). The system does require a previously densified control network and movement of sights.

Currently, Districts 4 and 8 have complete remote observation systems that are available for loan to other districts. When loaned to another district, the trained staff are provided to operate the system.

**Production:** Once the monumentation for the primary control is set, production rates of 1200 to 1600 m per day can be expected for 4 to 5 breaklines (one roadway). Additional lines do not significantly increase overall time as long as the lines are on the traveled way.

#### **4. Photogrammetric Pavement Elevations:**

**Description:** General photogrammetric mapping standards require that 90 percent of spot elevations be within 25 percent of the contour interval; i.e., for 1:500 mapping (0.5 m contours), elevations are  $\pm 0.125$  m. This accuracy will not meet normal requirements for pavement elevation surveys.

In the fall of 1996, the ESC Photogrammetry Section has initiated a new service called Photogrammetric Terrain Lines (PTL). PTL is based on the acquisition of low altitude photography, using an aerial camera mounted in a helicopter. The demonstrated accuracy of PTL is 1/10,000 of the flying height above mean terrain. With a typical flying height of 300 feet, accuracy of survey data points are within 11 mm, vertically.

The number of ground control points for the PTL method must be substantially increased over that provided for conventional photogrammetric projects. The vertical accuracy of the points must also be greater. For these reasons, costs for PTL ground control are significantly higher than for conventional photogrammetry projects.

The Project Surveyor should recommend photogrammetry to the Project Manager as a possible method for obtaining pavement elevations because no lane closures are necessary and impact on traffic is minimal. Also, the exposure of field surveyors to traffic is dramatically reduced.

For more information on photogrammetric services, see Section 15, "Photogrammetric Surveys." Consult your district Photogrammetry Coordinator or the ESC Photogrammetry Section to determine if a PTL photogrammetric survey is appropriate for project requirements.

### **11.7-5 Utility Surveys**

Utility surveys are undertaken to locate existing utilities for (a) consideration in engineering design, (b) purposes of utility relocation, and (c) right-of-way acquisition and negotiation.

Survey limits and types of utilities to be located should be shown on the Survey Request and/or its attachments. The field survey file should include all utility maps and drawings and descriptions of easements.

For additional information, refer to *Manual on High and Low Risk Underground Facilities Within Highway Rights of Way*.

It is important to locate all significant utility facilities. The following are lists of facilities and critical points to be located for various utilities. Be sure to check the field package for any required special facilities not listed. Underground utilities should be potholed only if specifically requested on the Survey Request. Potholing is to be undertaken by the utility company.

### **Oil and Gas Pipelines**

- Intersection point with centerlines and/or right of way lines
- For lines parallel to right of way – location ties necessary to show relationship to the right of way lines
- Vents
- Angle points
- Meter vaults, valve pits, etc.

### **Water and Sewer Lines**

- Intersection point with centerlines and/or right of way lines
- For lines parallel to right of way – location ties necessary to show relationship to the right of way lines
- Manholes, valve boxes, meter pits, crosses, tees, bends, etc.
- Elevation on waterlines, sewer inverts, and manhole rings
- Fire hydrants
- Curb stops

### **Overhead Lines**

- Supporting structures on each side of roadway with elevation of neutral or lowest conductor at each centerline crossing point.
- On lines parallel to roadway, supporting structures that may require relocation, including overhead guys, stubs, and anchors.

**Underground Lines**

- Cables/lines (denote direct burial or conduit, if known), etc.
- Manholes, pull boxes, and transformer pads
- Crossing at centerline or right of way lines
- For lines parallel to right of way – location ties as necessary to show relationship to the right of way lines

**Railroads**

- Profile and location 60 m each side of the proposed roadway right of way lines.
- Switch points, signal, railroad facilities, communication line locations, etc.

**Method:** TSSS radial survey, GPS fast static, kinematic or RTK.

**Accuracy Standard:** Data points located on paved surfaces or any engineering works should be located within  $\pm 10$  mm horizontally and  $\pm 7$  mm vertically. Data points on original ground should be located within  $\pm 30$  mm horizontally and vertically.

**Checking:** Utility data should be checked by the following means:

- Compare field collected data with existing utility maps
- Compare field collected data with the project topo map/DTM
- Review profiles of field collected data
- Include field collected data, which have elevations, in project DTM
- Locate some data points from more than one setup

**Product:** The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- CAiCE DTM surface files (CAiCE project subdirectory)
- 3-D digital topographic map (Intergraph, .dgn, format)
- Hard copy topographic map with border, title block, labeled contours, and planimetry
- File of all surveyed points with coordinates and descriptions (CTMED, .rpt, format)

### 11.7-6      **Archaeological Site/Environmentally Sensitive Area Survey**

Archaeological and environmental site surveys are performed for planning and engineering studies. Surveys staff must work closely with the appropriate specialists and the survey requestor to correctly identify archeological and environmentally sensitive data points.

**Method:** TSSS radial survey, GPS fast-static, kinematic or RTK

**Accuracy Standard:** Data points located on paved surfaces or engineering works should be located within  $\pm 10$  mm horizontally and  $\pm 7$  mm vertically. Data points on original grounds should be located within  $\pm 30$  mm horizontally and vertically. Review field survey package for possible higher required accuracy.

**Checking:** Check data points by various means including, reviewing the resultant DTM, reviewing breaklines in profile, and locating some data points from more than one setup.

**Product:** The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- 3-D digital graphic file of mapped area (Intergraph, .dgn, format)
- Hard copy topographic map with border, title block, and planimetry (contours and elevations only if specifically requested)
- File of all surveyed points with coordinates and descriptions (CTMED, .rpt, format)

### 11.7-7      **Spot Location or Monitoring Surveys**

Monitoring surveys are undertaken for monitoring wells, bore hole sites, and other needs.

**Method:** TSSS radial survey, GPS fast static or kinematic

**Accuracy Standard:** Data points located on paved surfaces or any engineering works should be located within  $\pm 10$  mm horizontally and  $\pm 7$  mm vertically. Data points on original ground should be located within  $\pm 30$  mm horizontally and vertically.

**Checking:** Observe data points with multiple ties. See Section 7.4-2 “TSSS Specifications - Methods.”

**Product:** The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- File of all surveyed points with coordinates and descriptions (CTMED, .rpt, format)
- Sketch or map showing locations of data points

## 11.7-8      **Vertical Clearance Surveys**

Vertical clearance surveys are undertaken to measure vertical clearances for signs, overhead wires and bridges.

**Method:** TSSS radial method. See CTMED manual for appropriate topo codes.

**Accuracy Standard:** Data points located on paved surfaces or any engineering works should be located within  $\pm 10$  mm horizontally and  $\pm 7$  mm vertically. Data points on original ground should be located within  $\pm 30$  mm horizontally and vertically.

**Checking:** Observe data points with multiple ties. See Section 7.4-2 “TSSS Specifications – Methods.”

**Product:** The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- File of all surveyed points with coordinates and descriptions (CTMED, .rpt, format)
- Sketch or map showing vertical clearances

## **11.8 Office Data Processing**

Data processing includes preparing and checking survey products for delivery to the survey requestor. Processing, editing, and transferring data is all done using the Caltrans Data Processing (CTDAP) program (see CTDAP Manual). Supplemental control established during the engineering survey must be adjusted by least squares constrained to existing project control before calculating coordinates for topographic data points.

### **11.8-1 DIM Processing**

The primary steps in processing a DTM are:

1. Use CTDAP to create a survey database (.sdb) file, adjust control network, compute adjusted coordinates (x,y,z) for all DTM data points, edit known coding problems and create a Total Station Survey (.tss) file.
2. Review .tss file to verify checks shots and validate field procedures such as proper entry of instrument and prism height.
3. Import the .tss file into a DTM program (currently CAiCE).
4. Check the survey chains (DTM breaklines) in plan and profile for errors: incorrect positions, points skipped, crossing breaklines, and mislabeled data.
5. Generate parallel breaklines from standard cross sections in survey notes: for instance, from measured curb flowline, generate lip and top of curb.
6. Create DTM surface database, calculate DTM triangles, compute DTM contours.
7. Check the DTM by creating “freehand” cross sections from the DTM contours.
8. Return to step 1 and make corrections to database noted from steps 3-7 and create corrected .tss file. Repeat steps 3-8 as necessary.
9. Import corrected .tss file into CTMED on workstation.
10. Import .tss file into DTM program on workstation (currently CAiCE).
11. Repeat steps 4-7 as necessary, making any needed corrections to data base in CTMED.

Steps 1-8 are normally done on a PC either in the office or field. Steps 9-11 are done on the HP Workstation.